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Figure 5 is a block diagram of lighting system with a PV pan 1;

Figure 6 is a front view of power control unit;

Figure 7 is a wiring diagram and specs for two lamp ballast;

Figure 8 is a wiring diagram and specs for single lamp ballast;

Figure 9 is a front view of battery enclosure; and

Figure 10 is a block diagram of power control unit.

Figure 11 is a block diagram of an alternate lighting system using natural gas cogeneration.

INSERT A GOES HERE

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a block diagram of the major components of an uninterruptable lighting system of this invention. It may be installed anywhere conventional building lighting is required. Unlike emergency lighting, this is a full service, high quality lighting product. It functions with standard fixtures and lamps, without compromise in output quality and with no flicker in the event of a power failure. This permits normal building activities to continue for several hours using battery storage without disruption of work activity due to loss of lighting. The key subsystem that ties the entire system together is the power control unit 1 which normally uses AC grid power to supply the lighting energy and keep the battery 2 charged. The lighting fixtures 3 are fluorescent tubes using electronic ballasts which have a low voltage (nominal 26.6 volts) DC input supplied by line 5 from power control unit (PCU) 1. During a power outage, the DC line 5 is supplied by battery 2.

Figure 2 shows a physical block diagram showing the AC electric service panel 6 with a three wire cable

(THIS IS INSERT A)

Figure 12 (fig. 2 in patent 5500561) is a block diagram of a customer side, power management system formed in accordance with patent 5500561 and illustrating its interface with existing electric utility power lines of the customer facility.

Figure 13 (fig. 3 in patent 5500561) is a schematic diagram of an alternate power management system formed in accordance with patent 5500561.

Figure 14 (fig. 2 in patent 5786642) illustrates the invention with regard to incorporation of the linear voltage regulator and control interface of patent 5555561 as one means for controlling the charge level of the storage battery.

Figure 15 (fig. 3 in patent 5786642) illustrates the use of circuit breaker means and looping of a DC lighting circuit as well as auxiliary DC equipment and an inverter associated with a simplified illustration of the electric distribution box.

Figure 16 (fig. 4 in patent 5786642) illustrates a converter fed by a DC supply from a rectifier and providing an output to storage battery means illustrated as having a filter capacitor in electrical parallel therewith.

the power junction means. Other voltages ar also possible, such as 13.3, 26.6, 39.9 etc.

The Battery Undervoltag Cut-Off disconnects th batt ry in situations of d pletion to prevent "over sulfation" or chemical and physical damage to the storage battery. The PV Voltage Regulator and Suppressor is a power conditioner block to suppress voltage transients (such as from lightning strikes in the vicinity) and also to prevent over charging of the storage battery from the PV panel.

[illegible] include power limiting [illegible]

Figure 11 is an alternate embodiment for a loadside powered lighting system including natural gas in a cogeneration component. AC power 50 is normally converted to DC power by DC power converter 51 and control means 52. However, a cogenerator in the form of a DC gas generator 53 receives natural gas from a natural gas source 54, and sends DC power to building lighting system 55, such as electronic ballasted fluorescent lighting. This system provides a flatter and more predictable power demand for electric utility customers at building lighting system 55, since it supplants peak power from electric utility generating sources. This results in reduced demand charges, since gas offers a lower cost per unit of energy consumed, compared to conventional AC power from a public utility.

Load Leveling

The cogeneration system can run continuously for lighting load 55, without having to be sent back to AC line power 50, which avoids the need for costly AC synchronization methods and sine wave purity, as is needed when sending excess electricity back to a public utility.

DC gas generator 53 directly couples to building lighting system 55 through a diode isolator that allows either AC or DC power to operate building lighting system 55.

INSERT B GOES HERE

INSERT B ①





It is yet a further object of the present invention to provide a customer side, power management system and method which may automatically and substantially increase the efficiency of power usage by the customer in major load areas, such as lighting and other electronic loads, relative to other approaches.

In accordance with one form of the present invention, a customer side, power management system includes a power transducer having one or more sensors connected to the utility's power lines coming into the customer's facility. The power transducer measures the power being drawn by the customer's facility, and provides a signal proportional to the power drawn.

The system may further include an integrator connected to the output of the power transducer. The integrator averages the signal from the transducer for a predetermined integration period, in much the same way as a utility measures peak power consumption. The output signal from the integrator is provided to one input of a comparator circuit (or a differential amplifier circuit which, in effect, acts as a comparator), which is also included in the system.

The other input of the comparator circuit is connected to either an automatically adjustable set point circuit or a manually adjustable set point circuit, either of which can be coupled to the comparator circuit by an appropriate switching circuit. The set point circuits provide a threshold signal to the comparator circuit.

The comparator circuit compares the signal from the integrator with the set point circuit's threshold signal, and provides an output signal of at least one magnitude if the integrator's output signal is greater than or equal to the threshold signal, and of at least another magnitude if the integrator's output signal is less than the threshold signal.

The power management system of the present invention further includes an AC-to-DC convertor, which is preferably a switching mode type power supply. The power supply has a control input to which is provided the output signal from the comparator (or differential amplifier) circuit. The switching power supply receives at least a portion of the AC power provided by the utility to the customer's facility, and converts this portion to DC power on its outputs.

The DC power from the switching mode type DC power supply is provided to an isolation and distribution circuit and to a storage device, such as a battery. The isolation and distribution circuit will control and direct power to a load from either the DC power supply or the storage battery or proportionally from both, in accordance with the quantity of power consumed by the facility and sensed by the power transducer of the system.

These and other objects, features and advantages of this invention will become apparent from the following detailed description of illustrative embodiments thereof, which is to be read in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a graph of demand for electric power versus time for a constant lighting load of a hypothetical customer facility.

FIG. 1B is a graph of demand for electric power versus time for semi-random punctuated loads of a hypothetical customer facility.

FIG. 1C is a graph of demand for electric power versus time for semi-random longer cycle loads of a hypothetical customer facility.



FIG. 1D is a graph of demand for electric power versus time for a hypothetical customer facility and illustrating the composite idealized daily load profile for such a facility.

FIG. 2 is a block diagram of a customer side, power management system formed in accordance with the present invention and illustrating its interface with existing electric utility power lines of the customer facility.

FIG. 3 is a schematic diagram of an alternative power management system formed in accordance with the present invention.

FIG. 4 is a graph of demand for electric power versus time, which is similar in many respects to FIG. 1D, illustrating the results of load clipping by employing the system and method of the present invention.

FIG. 5 is a graph of demand for electric power against time similar in many respects to FIG. 4, illustrating the daily load profile of a hypothetical customer facility with the power management system of the present invention operating in the facility.

## ~~DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS~~

(from patent 5500561)

Referring now to FIG. 12 of the drawings, it will be seen that a customer side, power management system formed in accordance with the present invention may be easily interconnected with the existing electric power wiring of the customer facility to monitor the load requirements of the customer. To facilitate an understanding of the invention, FIG. 12 shows three phase power wiring (i.e., wires labeled L1, L2 and L3 representing each phase) and a neutral (i.e., N) wire coming from the utility and being received by the customer facility. The three phase wires, L1, L2 and L3 and the neutral wire N are received by a main distribution panel 202 of the customer facility. The main distribution panel 202 distributes the power throughout the facility, and in many cases provides power to a lighting distribution panel 204 which, as its name implies, distributes power to the various lighting circuits of the facility. That is, the main distribution panel 202 conventionally distributes the three phase power wiring of the electrical utility throughout the consumer facility and in so doing distributes power to the various loads served by the customer facility. ~~As is illustrated in FIGS. 1A–1C,~~ There are three types of very common AC electrical loads which may be required to be satisfied by the AC electrical power generated at the public or electrical facility and emanating from the illustrated consumer facility and they are a Lighting Load ~~(see FIG. 1A)~~, Semi-Random Punctuated Loads (see FIG. 1B), and Semi-Random Longer Cycle Loads ~~(see FIG. 1C)~~. Thus, the three phase power wiring L1, L2, and L3 and the neutral wiring N connects from the public utility side of the main distribution panel 202 and issues therefrom as AC electrical conductors on the customer side of this panel into connection with the composite of loads which are required to be satisfied by the power emanating from the electrical utility. ~~as shown in FIGS. 1A–1C~~ Normally, the main distribution panel 202 and the lighting distribution panel 204 are interconnected by one or more power lines 206, including a neutral line 208, but for purposes of this invention, the interconnecting lines between the main distribution panel and the lighting distribution panel are interrupted, as illustrated by the broken lines in FIG. 12. It will be understood that the interruptions of the lines between the main distribution panel 202 and the lighting distribution panel 204 with introduction of the inverter 210 are necessary only if the Lighting Load is not capable of being

powered solely by direct current, as distinct from a situation where the Lighting Load may be powered, in whole or in part, by AC power. To the extent it is not so capable, the inverter 19 must be employed to supply AC power, all in the event that there could be failure of the electrical facility to deliver any AC at all. Patent 5500561

In accordance with ~~the present invention~~, the power management system includes a power transducer 210. The power transducer 210 has associated with it one or more voltage or current sensors 212, each sensor being coupled to a respective power line phase. The power transducer 210 measures in real time the power consumed by the customer facility from the electric utility, and provides an output signal corresponding to this measurement. The output signal provided by the power transducer 210 is proportional in magnitude to the power consumed by the customer facility. For example, the output signal may be in terms of voltage, and have a range of from 0 to +10 or −10 volts, which would correspond to a power consumption of from 0 to 100 kilowatts. A suitable power transducer 210 which may be used for the power management system of the present invention is Part No. PCE-20 manufactured by Rochester Instrument Systems, Inc.

The output signal from the power transducer 210 is preferably provided to an integrator circuit 214. The integrator circuit 214 averages the real time power measurement made by the power transducer. The integrator circuit 214 simulates the operation of a similar integration circuit which the utility uses to average the peak power demands of its customers.

The integrator circuit 214 may be formed in various ways, including using an operational amplifier 216 with a feedback capacitor 218 and an input resistor 220, as shown in FIG. 2. The values of capacitor 218 and resistor 220 are selected to provide a desired integration time. The integrator circuit 214 shown in FIG. 2 provides a negative gain; accordingly, if such a circuit is used, it may be coupled to the 0 to −10 V output of the power transducer to provide a positive output voltage signal which varies in response to changes in power drawn from the utility and sensed by the sensor 212.

The power management system of ~~the present invention~~ Patent 5500561 further includes a comparator circuit which, in a preferred form, is a differential amplifier circuit 220. The output of the integrator circuit 214 is provided to a first input of the differential amplifier circuit 220. A second input of the differential amplifier circuit 220 is connected to a switching circuit 222, which is functionally depicted in FIG. 2 as a single pole, double throw switch 222a.

More specifically, the "wiper" arm 224 of the switching circuit is connected to the second input of the differential amplifier circuit 220, one pole 226 of the switching circuit is connected to an automatically adjustable set point circuit 228, and the other pole 230 of the switching circuit is connected to a manually adjustable set point circuit 232.

The automatically and manually adjustable set point circuits 228, 232 provide a threshold signal, which may be in the form of a voltage, through the switching circuit 222 to the second input of the differential amplifier circuit 220. The threshold signal represents the power level at which a secondary source of DC power, such as a storage battery 234, forming part of the power management system is to take over in supplying power to one or more various loads in the customer's facility, as will be described.

Various manually adjustable set point circuits are envisioned to be used in the present invention. One example of such is a potentiometer 236 connected between positive and negative voltages or a voltage V1 and ground, with its wiper arm connected to the pole 230 of the switching circuit 222. Such a circuit would provide a threshold voltage to the differential amplifier circuit 220. The set point circuit 232 would be adjusted after an analysis of the customer's energy consumption profile. The threshold would be set so that any stochastic or recurrent (i.e., non-random, time of day) peaks in the customer's daily power demand would be supplied in full or proportionally by the secondary DC power source of the power management system, as illustrated by FIG. 3.

The automatically adjustable set point circuit 228 will periodically derive and store the maximum value of the actual peak power demands over predetermined time intervals, for example, daily or monthly, and provide a threshold which is based on a "moving average" computed by the circuit. This threshold signal is provided to the input of the differential amplifier circuit 220 through the switching circuit 222. The automatic set point circuit 228 will automatically adjust the threshold signal in accordance with the moving average of the customer's peak power requirements which it calculates algorithmically. An example of such a circuit is disclosed in U.S. Pat. No. 4,731,547, which issued to Phillip Alenduff et al., the disclosure of which is incorporated herein by reference.

As its name implies, the comparator (or more preferably the differential amplifier) circuit 220 will compare the threshold signal provided by either set point circuit ~~28, 32~~ which is ←228, 232 selected by the switching circuit 222 with the output signal from the integrator circuit 214, which output signal represents the power being drawn from the utility averaged over the predetermined integration period. If the output signal from the integrator circuit 214 is greater in magnitude than the threshold signal, i.e., indicating that excessive or peak power is being consumed, the differential amplifier circuit 220 will sense this and provide a proportional output signal which is compatible with that required to control an AC-to-DC converter or switching mode type power supply 238 forming part of the power management system, as will be described.

One form of a differential amplifier circuit 220 which is suitable for use in the present invention is an operational amplifier 240 having a feedback resistor 242 and an input resistor 244, with the threshold signal being provided to the inverting input of the operational amplifier 240 through the input resistor 244, and the output signal from the integrator circuit 214 being provided to one side of a second input resistor 243 whose other side is connected to the non-inverting input of the operational amplifier and to another resistor 245 to ground. When the values of the first input and feedback resistors ~~44, 42~~ equal those of the second input and ←244, 242 the grounded resistors ~~43, 45~~, respectively, the output signal ←243, 245 from the differential amplifier circuit 220 will be a voltage level equal to the difference between the voltage levels of the integrator circuit's output signal and the threshold signal, multiplied by the ratio between the values of the feedback and first input resistors ~~42, 44~~. Accordingly, the output signal 242, 244 from the differential amplifier circuit 220 is preferably a voltage level which varies proportionally with the difference between the output signal from the integrator circuit 214 and the set point threshold signal level.

As will be described in greater detail, many AC-to-DC power supplies adjust their output voltage levels in proportionment to the voltage applied to their control signal input, and operate on positive control signal voltages, for example, 0 volts to 10 volts for an output adjustment of from 125 volts to 110 volts. To prevent negative voltage swings in the output signal from the differential amplifier circuit 220, such as when the level of the output signal of the integrator circuit is below the set point threshold signal level, one can provide

a positive supply voltage to the appropriate supply terminal of the operational amplifier 240, and ground the negative supply terminal. Alternatively, one may connect a diode (not shown) having its anode connected to ground and its cathode connected to the output of the operational amplifier 240 to clamp the differential amplifier's output signal to 0 volts when the output signal from the integrator circuit 14 is less than the set point threshold signal level.

Instead of using the differential amplifier circuit 220, which provides a continuously variable output signal which is proportional to the difference between the threshold signal and the integrator circuit's output signal, a simple comparator, such as in the form of an operational amplifier, may be used. The integrator's output signal and the threshold signal are provided to the two inputs of the comparator, and the comparator's output signal is provided to the control input of the AC-to-DC converter 238. When the integrator circuit's output signal is greater than the threshold signal, the output signal of the comparator will be in a first state to signal the AC-to-DC converter 238 to provide a first output voltage level. When the integrator circuit's output signal is less than or equal to the threshold signal, the output signal of the comparator will be in a second state to signal the AC-to-DC converter 238 to provide a second output voltage level.

As mentioned previously, the power management system of the present invention includes an AC-to-DC converter circuit 238. Preferably, the converter circuit 238 is a power supply of the switching type, which is known to have good regulation and high efficiency. The power line 26 and neutral line 28 from the main distribution panel 22, which originally were provided to the lighting distribution panel 24, are now provided to the AC inputs of the switching power supply 238. The output signal from the comparator or differential amplifier circuit 220 is provided to the control input of the power supply. The switching power supply 238 will convert the AC power provided to it into a DC voltage and current to run a particular load or loads at the customer facility, such as a fluorescent lighting load 246, as illustrated by FIG. 12. A suitable AC-to-DC switching power supply 238 which may be used in the power management system of the present invention is Part No. 2678644 manufactured by Technal Power Corp., a Penril Company, located in Connecticut. For greater power handling requirements, several power supplies may be connected in parallel, all being controlled by the comparator or differential amplifier circuit 220. With whichever AC-to-DC converter 238 that is used, the comparator or differential amplifier circuit 220 is designed to provide the compatible control signal to vary the converter output as required.

The output voltage of the switching DC power supply 238 is adjustable proportionally to the control signal it receives. For example, the power supply 238 may be selected or designed such that a control voltage provided to the control input of the power supply of from 0 to 10 volts will inversely adjust the output DC voltage of the power supply from 125 to 110 volts. As will be described in greater detail, the control of the output voltage of the AC-to-DC power supply 238 is an important aspect of the power management system, as it will allow the lighting or other load to be driven by power from the electric utility or from the secondary DC source, such as the storage battery 234, situated at the customer facility.

The DC output voltage from the AC-to-DC power supply 238 is provided to a power isolation and distribution circuit 48 and to a second source of DC power which, in the preferred form of the invention, is a storage battery 234. More specifically, the positive terminal of the power supply 238 is provided to the input of the power isolation and distribution circuit 248, one output of the power isolation and distribution circuit is provided to the power line 26 connected to the lighting distribution panel 24, and another output of the power isolation and distribution circuit is provided to the positive terminal of the storage battery 234. The negative output of the power supply 238 is provided to the negative output of the storage battery 234 and to the neutral line 28 connected to the lighting distribution panel 4. Connected in this manner, the AC-to-DC power supply 238 will not only provide DC power to the lighting or other load 26 of the customer, but will also (246) charge the storage battery at times of low power demand.

In a preferred form of the present invention, the power isolation and distribution circuit 248 basically consists of a series of three interconnected diodes ~~50,52,54~~. The first 250,252,254 diode 250 has its anode connected to the positive output terminal of the power supply 238, and its cathode connected to the positive terminal of the storage battery 234. The second diode 252 has its anode connected to the positive terminal of the storage battery 234, and its cathode connected to the first output of the power isolation and distribution circuit 248, which output is connected to the power line 26 provided to the lighting distribution panel 24. The third diode 254 has its anode connected to the positive output terminal of the power supply 238, and has its cathode connected to the cathode of the second diode 252 and to the first output of the power isolation and distribution circuit 248.

The diodes of the power isolation and distribution circuit provide isolation between the storage battery 234 and the AC-to-DC power supply 238, and provide a larger "dead band" or buffer region to allow the storage battery to be switched into the circuit, to supply power to the lighting or other load 246, or isolated from the circuit. The diodes ~~50-54~~ 250-254 used in the power isolation and distribution circuit are preferably high power, silicon diodes.

The power isolation and distribution circuit 248, power supply 238 and storage battery 234 work in the following manner. Assuming the storage battery is 124 volts DC, and the output of the AC-to-DC power supply is 125 volts DC, 250,254 for example, then the first and third diodes ~~50,54~~ are forward biased so that the potential at the first and second outputs of the power proportioning circuit is 124.3 volts each, assuming diode drops of 0.7 volts. The second diode 252 is essentially back biased and not turned on. The DC power supply 238 is supplying current to the lighting or other load 246 as well as to the storage battery 234 to charge the battery. This condition occurs during times when there is no peak power demand.

If, for example, the output of the AC-to-DC power supply 250,254 decreases to 123 volts, then the first and third diodes ~~50,54~~ of the power isolation and distribution circuit are back biased, and the second diode 252 is forward biased. Under such conditions, the storage battery 234 contributes power to the lighting or other load. This condition occurs during peak power demands. The amount of power contributed by the battery 234 to the load is substantially equal to the amount of power drawn from the utility by the customer which exceeds the set point threshold, up to the limit of the load.

For example, assume that the customer demand is 750 K watts, the set point threshold is set at 800 K watts, and the lighting load controlled by the power management system of the present invention is 100 K watts. Since the customer demand is below the peak set point threshold, the lighting load of the customer will be entirely powered by the utility through the AC-to-DC converter, and the storage battery 234 is being recharged under these conditions. This can be

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considered a first mode of operation of the power management system.

Assume now that the customer's demand has increased to 850 K watts, which is 50 K watts over the 800 K watt set point threshold set in the management system. Under such conditions, the lighting load controlled by the system will draw 50 K watts of power from the utility through the AC-to-DC converter 238 and 50 K watts of power from the storage battery. Thus, there is a proportional sharing of power to the load from the utility and the storage battery to provide power to the lighting or other load. This can be considered a second mode of operation of the system.

If customer demand increased to 1000 K watts, which is 200 K watts above the threshold, the lighting load will be powered entirely from the storage battery and not by the utility. This is a third "uninterruptable" mode of operation of the system.

Preferably, the storage battery 234 is formed from a series connection of ten, 12 volt DC batteries. One form of battery which is suitable for use is a sealed, maintenance free lead acid Absolyte(TM) series of batteries manufactured by GNB, Inc.

Patent 5500561 The operation of the power management system of ~~the present invention~~ will now be described. A stochastic or recurrent peak power demand, ~~such as shown in FIG. 11,~~ is detected by the power transducer 210. The voltage level of the output signal from the power transducer will increase, and this increase in voltage level will be averaged over a predetermined integration period by the integrator circuit 214. The output signal of the integrator circuit will accordingly also increase in magnitude. If the output signal level of the integrator circuit 214 is greater than the threshold signal level 228, 232 of either set point circuit ~~28,32~~ connected to the system, the comparator or differential amplifier circuit 220 will sense this and provide an appropriate output signal to the AC-to-DC power supply 238 to reduce the power supply output voltage to below the potential of the storage battery 234. Since the battery potential is greater than the power supply voltage, power from the battery 234 will be supplied to the load.

If electric power demand from the utility decreases, a corresponding decrease in the magnitude of the output signals from the power transducer 210 and the integrator circuit 214 will follow. If the output signal from the integrator circuit falls to or below the threshold level set by the set 228, 232 point circuits ~~28,32~~, the comparator or differential amplifier circuit 220 will sense this and will provide the appropriate signal to the control input of the switching power supply 238 to increase the output voltage level of the power supply. If the supply's output voltage level is greater than the present or "spot" potential of the storage battery 234, the load will again be fully served by the power supply, and current will also flow to the battery until the battery is fully charged. In this mode, no current will flow from the battery to the load.

Patent 5500561 Another form of the power management system of ~~the present invention~~ is shown schematically in FIG. 13. The power transducer 210 is connected to one or more of the customer's utility power lines, as shown in FIG. 12, and has its output connected to the non-inverting input of an operational amplifier 260 configured as a non-inverting buffer amplifier. The output of the buffer amplifier 260 is connected to one side of a differential amplifier circuit including an operational amplifier 240, a first input resistor 243 connected between the buffer amplifier output and the non-inverting input of the operational amplifier 240, and another resistor 245 connected between the non-inverting input of the operational amplifier and ground. The differential amplifier includes another input resistor 244 connected to the inverting input of the operational amplifier 240, a feedback resistor 242 connected between the output and inverting input of the operational amplifier and a feedback capacitor 262 connected in parallel with the feedback resistor. The input resistors 243, 244 ~~43,44~~ are preferably equal in value, as are the feedback resistor 242 and grounded resistor 245, as in the previous embodiment. The feedback capacitor 262 is provided to slow the response time of the differential amplifier.

A manual set point threshold circuit includes a potentiometer 236 having its opposite legs connected between a positive voltage and ground and its wiper provided to the non-inverting input of an operational amplifier 264 configured as a non-inverting buffer amplifier. The output of the buffer amplifier 264 is provided to the other input resistor 244 of the differential amplifier.

The output of the differential amplifier is provided to a voltage-to-current converter. The voltage-to-current converter includes an NPN transistor 266, a base resistor 68 connected between the output of the differential amplifier and the base of the transistor 266, and an emitter resistor 270 and series connected diode 272 which together are connected between the emitter of the transistor and ground. The collector of the transistor 266 is connected to one end of a fixed resistor 274 and one end and the wiper of a multi-turn potentiometer 276, whose other end is connected to ground. The remaining end of the fixed resistor 274 is connected to the Adjust input of a series regulator 278, such as Part No. TL783C manufactured by Texas Instruments, and to one end of another fixed resistor 280 whose other end is connected to the output (OUT) of the regulator 278.

As in the previous embodiment, the power management system includes an AC-to-DC converter comprising the regulator 278 mentioned previously, a full wave rectifier circuit consisting of two diodes ~~82,84~~, and a conventional pi 282, 284 filter consisting of two by-pass capacitors ~~90,92~~ and a series 290, 292 choke or inductor 294, the filter circuit being connected to the output of the rectifier circuit. The output of the filter circuit is connected to one leg of a fixed resistor 296, whose other leg is connected to the input (IN) of the regulator 278 and to the base of a PNP transistor 298 through a base resistor 100. The emitter of the transistor 298 is connected to the output of the filter circuit, and the collector is connected to the base of an NPN power transistor 102. A suitable power transistor 102 which may be used is Part No. TIPL762 manufactured by Texas Instruments. Of course, the power transistor is selected in accordance with the power requirements of the system. The collector of the power transistor 102 is connected to the emitter of its driving transistor 298 and to the output of the filter, and the emitter of the transistor 102 is connected to the output of the regulator 278. Transistors 298 and 102 and their associated components form a current booster circuit. From (patent 5500561)

The power management system shown in FIG. 13 further includes an isolation and distribution circuit consisting of three interconnected first, second and third diodes ~~50,52,54~~, 250, 252, 254 as in the previously described embodiment illustrated by FIG. 12. The output of the regulator 278 is connected to the anodes of first and third diodes ~~50,54~~. 250, 254 The anode of the second diode 252 and cathode of the third diode 254 are connected to the positive terminal of a storage battery 234 used in the power management system, and the cathodes of the second and third diodes ~~52,54~~ 252, 254 are connected to the load 246 which is powered by the system.

The power management system shown in FIG. 13 operates in the following manner. When the power drawn from the

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utility is such that the output level of the transducer 210 is below the set point threshold level, the transistor 266 of the voltage-to-current converter is non-conducting. This effectively increases the resistance of the lower leg of a resistor divider network defined by resistor 280, comprising the upper leg, and the combination of resistors 274 and the parallel combination of the multi-turn potentiometer 276 and the resistance of the voltage-to-current converter, which comprise the network's lower leg. Under such conditions, the voltage at the anode of the first diode 250 will be greater than the voltage at the anode of the second diode 252, which is the voltage of the storage battery 234. The first diode 250 will be turned on and the second diode 252 will be back biased so that power from the utility through the AC-to-DC converter, i.e., the full wave rectifier circuit, the filter and the current booster circuit, will be provided to the load 246.

When the transducer 210 of the power management system senses an increase in utility power drawn by the customer, the output signal from the buffer amplifier 260 will exceed the magnitude of the output signal of the threshold signal's buffer amplifier 264. In response, the differential amplifier will provide a positive voltage output signal which will cause the transistor 266 of the voltage-to-current converter to conduct current. This effectively lowers the resistance of the lower leg of the resistor divider network which, in turn, decreases the voltage on the anode of the first diode 250. If the voltage on the anode of the first diode 250 decreases to a point where the second diode 252 is forward biased, current will flow from the storage battery 234 to the load. As now less power is drawn from the utility, the output voltage from the power transducer 210 will decrease, which affects the output voltage of the differential amplifier and the current drawn through the collector of the voltage-to-current converter transistor 266. This will change the voltage on the anode of the first diode 250 to a point where there is a proportional sharing of power from the storage battery and from the utility. Thus, the power management system acts as a servo system with feedback and has a self-leveling capability.

As can be seen from the above description, the power management system of ~~the present invention~~ can be easily implemented in a customer facility with little or no rewiring. Because the main distribution panel 2 is usually connected to a second, lighting distribution panel 4, the interconnection between the two can be broken and connected to the power management system. Also, fluorescent lighting, which may represent approximately 40% of the total load for some utility customers, is a particularly attractive load to work in conjunction with the power management system. The lighting load remains fairly constant throughout the day and, therefore, the power management system parameters may be easily optimized for operating such a load. In addition, many of the electronic ballasts currently, and increasingly, used in fluorescent lighting will function on either direct current (DC) or alternating current (AC). If fluorescent lighting, either electronically ballasted or magnetically ballasted, is to be controlled by the system and powered by AC, this may be accomplished by using an inverter 110 interconnected between the output of the power isolation and distribution circuit 248 (and the negative terminal of the AC-to-DC converter 0.38) and the lighting distribution panel 4, as shown by dashed lines in FIG. 2. Accordingly, fluorescent and other lighting is perfectly suited for operation with the power management system of ~~the present invention~~.

patent 5500561

The power management system of the present invention is designed to remove stochastic or recurrent peak loads from the customer's electric utility power line, to the principal financial advantage of the customer in avoiding demand



charges, as illustrated by FIG. 4 of the drawings, which shows by dashed lines the elimination of such peaks from the customer's utility demand. Also, the power management system provides for load shifting, to the principal advantage of the power utility. The threshold is adjustably set by the system to remove and shift such demand loads, as illustrated by FIG. 5 of the drawings.

A typical customer load profile is shown by the solid line in FIG. 5, with a peak in the profile occurring at or about 1:00 p.m. During the peak period, the power management system automatically turns on to reduce the utility power consumed. During such times, the storage battery 34 is mainly discharging, as represented by the letter D in FIG. 5, to provide power to the lighting or other loads. This reduces the customer load profile to that illustrated by the dashed line in FIG. 5.

At times of low power demand, the power management system will charge the storage battery 34, as described previously. The periods that the battery is charging are indicated by the letter C in FIG. 5. This load shifting may also be performed at preset times. As illustrated by FIG. 2, the connection between switching circuit 22 and the differential amplifier circuit 20 may be broken, as illustrated by dashed lines, to add a relay or switching circuit 112 between the two. Relay or switching circuit 112 is functionally depicted as a single pole, double throw switch 112a, with its wiper 114 connected to the differential amplifier circuit 20 and one pole 116 connected to wiper 24 of switching circuit 22. The remaining pole 118 may be connected to a voltage source V having a magnitude which is less than that of the output signal from the integrator circuit 14 or power transducer 10 expected during the periods when load shifting is desired.

A timing circuit 120 is coupled to the relay or switching circuit 112 to control the circuit such that, at predetermined times, the connection between switching circuit 22 and differential amplifier circuit 20 will be broken by relay or switching circuit 112, and voltage V will be applied to differential amplifier circuit 20 through relay or switching circuit 112. Because voltage V is selected to be less than the output voltages of integrator circuit 14 and power transducer 10, the output signal of the differential amplifier circuit 20 will ensure that the output voltage of the AC-to-DC converter circuit 38 is lower than the potential of storage battery 34. Accordingly, battery 34 will provide predetermined power to the selected loads during programmed "on" times controlled by timer 120.

An external control input 122 may also be provided and connected to the relay 112 to allow an external control signal to switch the relay when load shifting is desired. The control input may optionally be connected to a modem 124 situated at the customer side so that, for example, the utility itself may remotely control when load shifting at the customer side is to occur by transmitting a signal to the modem 124 to control relay 112.

Since the utility charges a premium for peak power consumption, removal of stochastic or recurrent peak loads from the utility may significantly reduce the electricity charges incurred by the customer.

Since the storage battery 34 is only being used during infrequent times of peak power demands, the controlled depth of discharge and the charge and discharge cycle of the storage battery can be minimized. As a result, the life of the battery will be prolonged.

It should also be noted that other types of secondary power sources may be used, such as a power generator or

CONTINUE

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may be used to feed the AC loads AL powered by the box DBA. Similarly, the electric plug PL2 may be used to feed the intrinsic DC load means LM powered by the box DBD.

FIG. 1 illustrates a basic modular unit M which is external to the box EDB and therefore attains some surprising advantages which will now be explained. The basic modular unit M comprises the rechargeable storage battery means SB which represents the battery storage capacity to be drawn upon when DC power is not otherwise available to the consuming load. The storage battery means SB is chargeable in deep cycle fashion to a charge value at which an incipient electrolyte boiling point is reached and the battery charging means employed must be capable of effecting such charge value as will ensure this level of charge without either overcharging or undercharging.

An important aspect of this invention resides in the compound use of the "battery equivalent capacitance", inherent with the storage battery means SB, in conjunction with the filter capacitor FC. The magnitue of the "battery equivalent capacitance" gain per unit volume exhibited by the storage battery means SB is outstanding. To illustrate this point, a standard filter capacitor FC might have a capacitance measured in microfarads (say 50 microfarads) and be of a bulk or volume to fit easily within the box DB. The storage battery means will have a battery equivalent capacitance of at least 10,000 Farads. The high battery equivalent capacitance of the storage battery means is highly effective for AC ripple filtering but the bulk is too high for incorporation within the box EDB and, more importantly, it provides an ideal AC path to ground. If the storage battery means SB were to be removed, even temporarily, the limited AC path to ground supplied by the filter capacitor FC would be inadequate to provide an adequate AC path to ground, however, the presence of the DC power source DCPS, or its equivalent, provides the adequate path. By substituting a 12 volt deep cycle lead-acid battery means SB of say, 1 cubic foot volume, the relative "battery equivalent capacitance" would be at least 10,000 Farads. Stated otherwise, such storage battery means SB would provide a very large and adequate AC path to ground commensurate with the load current being drawn and the limited AC path to ground afforded by the filter capacitor FC would still be essential to comply with local electrical codes. The two capacitors operate in conjunction with one another and both are essential for complying with local codes, the means SB conducting current in opposite directions consistent with the requirements for AC conduction to ground and its associated DC power supply additionally providing a DC isolation path from ground, and the means FC providing a second, but limited, AC path to ground in the event that the means SB becomes disabled. In regard to the latter, the means FC is sized in capacitance wherein the capacitive reactance Xc is low enough to pass sufficient current to keep both the worst case fault currents well below any shock hazards and to allow sufficient current flow to trip the relevant circuit breaker(s) in the event of an appliance short circuit.

It will be appreciated that although the filter capacitor FC normally would be hard wired within the box EDB, it could be incorporated within the module M in parallel with the storage battery means.

As will be seen, AC potential is available at the wirings W20 and W22 because the power buss P2 is supplied with AC power and DC potential is available at the wirings W22 and W24 because of the presence of the storage battery means SB. Therefore, the plug openings 20 and 22 may be connected to the AC load means AL of the distribution box DBA through the prongs 20' and 22' of the electric plug PL1



and the plug openings 22 and 24 may be connected to the intrinsic DC load means LM of the electric distribution box DBD through the prongs 22" and 24" of the electric plug PL2.

As noted before, the illustration of FIG. 1 is somewhat simplified because only one AC power buss P2 is connected although other and different connections could be illustrated and only one DC power availability is illustrated between the wirings W22 and W24 although the electrical outlet EO1 could be much more complex and offer a great deal more in the way of AC and DC power capabilities. Such will be illustrated in greater detail hereinafter.

~~FIG. 2~~
14 (from patent 5786642)

With reference to FIG. 14, note that the circuit shown largely parallels FIG. 13 ~~of my copending application~~ wherein rectification is effected by the diodes 282 and 284 they feed the TEE circuit 294, 290, 292 of the voltage regulator section (so labelled) operating in conjunction with the control interface (so labelled) to output DC at the junction A. Thus, an important objective ~~of this invention~~ is realized, namely, that the charge level of the storage battery means SB to service an intrinsic DC load means such as 346 in FIG. 14 or the electronically (DC) ballasted fluorescent lighting circuit FL in FIG. 15 is maintained at the desired level. Note that the three modes of operation as disclosed in U.S. Pat. No. 5,500,501 obtain.

When AC input is present, the voltage regulator function illustrated in FIG. 14 is one means for maintaining the charge level of the storage battery means SB, contained within the module M and which is connected to the junctions J1 and J2 ~~(see FIG. 1)~~. The lighting load 346 is, of course, an intrinsic DC load means such as the looped LIGHTS circuits FL looped between the ground buss GB and the circuit breakers B5 and B6 which are connected to the neutral buss NB as in FIG. 15. ~~The DC power source DCPS of FIG. 1 is~~ The photo-voltaic panel means PV ~~of FIG. 2~~ and the inverter means INV are shown in ~~both~~ FIG. ~~1 &~~ 14. It will also be understood that although the electric distribution box ~~EDB~~ is not illustrated fully in FIG. 14; this is done for simplicity to avoid overcrowding of the Figure.

~~FIG. 3~~
(from patent 5786642)

FIG. 15 shows the electric distribution box EDB in simplified and uncluttered form and is principally directed to illustrating the concept of ganged circuit breakers and of looping of an intrinsic DC load means as well the use of a load source means. The box EDB is outlined and the ground buss GB, the neutral buss NB and the power buss P2 are all designated. The DC ballasted fluorescent lighting intrinsic DC load means FL comprises an example of a distributor box DBD emanating from the box EDB. Each looping WDBD54 and WDBD56 is between the neutral buss NB (−DC) through the circuit breaker means B5 and B6 to the ground buss GB (+DC). Four electrical outlet means EO1, EO2, EO3 and EO4 are illustrated, all identical, with the two wirings W20 connected with the power buss P2 through the respective circuit breaker means B1 and B3. Similarly, the two wirings W22 are connected with the neutral buss NB through the respective circuit breaker means B2 and B4. ~~The two circuit breakers B1 and B3 each correspond to the circuit breaker 14 in FIG. 1 whereas the two circuit breakers B2 and B4 each correspond to the circuit breaker 13 in FIG. 1.~~ The circuit breakers B1 and B2 "belong" to an AC path and a DC path, respectively, and the circuit breakers B3 and B4 similarly "belong".

~~Electric plugs PL1 and/or PL2 may be plugged in to the electric outlets with their prongs 20', 22', 24' and/or 20", 22", 24" as previously described.~~

The DC power sources ~~DCPS~~ are illustrated as the DC generator and the photo-voltaic panel means PV which, after regulation at the regulator 40, passes through the isolating diode D2 to the junction A to which the positive side of the DC generator DCPS is connected through the isolating diode D1. The junction A is connected to the ground buss GB through the circuit breaker B8 whereas the AC input from the inverter 50 is connected to the neutral buss NB by means of the wiring W50 and to the circuit breaker B7 through the wiring W52. The looping of the intrinsic DC load means effectively doubles the current carrying capacities of the associated wirings whereas the ganging of the AC and DC paths as to circuit breaker means allows the dual voltage aspect to be carried out with increased safety.

To reiterate some of the above, the modular concept of this invention is very important in that it involves the provision of separate entities which are the storage battery means SB and the filter capacitor means FC. The storage battery means SB has a very large battery equivalent capacitance consistent with an excellent AC path to ground and the filter capacitor means FC has a very small capacitance consistent with a limited AC path to ground and being sized in capacitance wherein the capacitive reactance Xc is low enough to pass sufficient current to keep both the worst case fault currents well below any shock hazards and to allow sufficient current flow to trip the relevant circuit breaker(s) in the event of an appliance short circuit. As noted, the capacitance of the filter capacitor FC should be in the order of 50 microfarads.

(From patent 5786642) ~~FIG. 1~~

FIG. 16 is directed to a circuit which embodies a switching type converter of very high efficiency and is a preferred form of converter because this type of DC-to-DC power supply represents high efficiency contemporaneously possible. FIG. 16 illustrates input mechanisms, some of which are not designated by reference characters but which are designated as to function, and also illustrates output mechanisms, none of which are designated by reference characters but which are designated as to function. In all such cases, the meanings should be clear and the additional descriptive material detailing the mechanisms and reference characters are believed to be unnecessary.

The block enclosed in dashed lines and designated by the reference character 501 is a typical full wave rectifier bridge circuit (i.e., the opposite of an inverter) feeding the capacitor 505 at the junction 501' and whose purpose is to reduce the rectified ripple component of the circuit 501 and provide filtered DC input voltage, present between the junction 501' and the conductor 501v, to the converter means.

The converter circuit shown, downstream of and as fed by filtered DC from the rectifier circuit 501, has junctions 521' and 521" within the section 521 between which the resistor/capacitor pair 521r and 521c are connected and which pair provide the further junction 521'". The junction 521'" is connected to the conductor 521v which supplies the pulse width modulator 503 with positive voltage Vcc, and this junction feeds the diode 521d1 having junctions with the parallel resistor/capacitor pair which are connected between the diode 521d2 and the junction 521".

The converter employs a pulse width modulator PWM, indicated at 503, controlling the switching transistor circuit 508 to impress transient voltage spikes present on the conductor 508v through the primary of the transformer 506 to cycle current to the primary windings L1 and L2 of the transformer 506 whereby "ac is generated as an intermediate process in the flow of energy" as is defined in the above definition of "converter". The secondary side of the transformer 506 is represented by the windings L3 and L4.

The circuit 509 is an optical isolation link between the pulse width modulator 503 and the control means 522 on the secondary side of the transformer 506 which allows control voltage on the conductor 509v emanating from the pulse width modulator 503 on the primary side of the transformer 506 to provide an input to the control means 522 on the secondary side to influence the pulse width modulator PWM 503 without current leakage back from the secondary circuit. Typically, the frequency of conversion effected by the transformer 506 will be 20,000–100,000 Hz which dictates the need for the special capacitor 517 to absorb these transients, the capacitance of the capacitor 517 being typically about 1 microfarad when used.

A secondary winding L4 drives the circuit 514 which, similarly to the rectifier 501 plus the filtering of the capacitor 505, provides a DC output, in this case the proper DC input to the control means 522 at the conductor 514v. The control means 522 has an output conductor 522o connected to the optical link 510 for controlling the three modes of operation of voltage control in accord with the principles of my prior applications. That is to say, when the optical isolator 510 link is "on", modes which permit DC current to flow from the photovoltaic means 520 are operative, i.e., either or both DC power input from the means 520 alone and partial or shared DC power input from the means 520. When the optical isolator 510 link is "off", the remaining mode, DC power input solely from another source, (i.e., no photovoltaic input) is effected.

The modes are controlled by the DC voltage prevailing across the junctions J1 and J2 (or the presence of a rechargeable DC mechanism such as a storage battery means connected to these junctions) in which case, mode 1, DC power input to the rechargeable DC mechanism alone, mode 2, shared DC power input, and mode 3 no DC power input to the rechargeable DC mechanism are the order of the day. That is to say, when the conductors 523 and 524 are connected to one of the DC sources illustrated in FIG. 16 or to a DC power source such as DCPS ~~in FIG. 1 or~~ in FIG. 3, the system will be fully operative for the purposes intended.

Stated another way, the DC voltage applied to the storage means will depend upon the feed back influenced by the resistors 336, 342, 343, 344, 345, 368, 370, 374 and 376 in FIG. 16 or by the resistors including 511, 512, 513 and 515 in FIG. 4.

This is true even if the system according to this invention is operated on the barest of input. For example, in locations where either AC or DC power is available only part of the time, or is available on site only from mechanism thereat, some configuration disclosed in the drawing Figures herein will be effective to provide DC power supply to the storage battery means. This therefore constitutes a universal power system. Add a SENTENCE

~~What~~ is claimed is:

1. A modular power management system having common wiring for allowing both AC and DC power therethrough comprising:

an electrical distribution panel capable of receiving both AC and DC power simultaneously;

a system of busses housed within the panel including electrical power buss means, neutral buss means and ground buss means;

a module unit including DC power supply means external to the panel connected across said neutral buss means and said ground buss means within said panel;